

Ascent Ground and Satellite Demonstration

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Big Picture Goals

- **Place more capable satellites into higher orbits**
- **Utilize software defined radios**
- **A programmable transponder that supports multiple linear and non-linear (FM) conversations simultaneously**
- **Digital modulation support**
- **Multi-users SHARING the Output Power**
- **Downlink assumed to be in X band (10.45 GHz), or greater**
- **Real time Doppler compensation**

Current Focus Goals

- **C-Band Uplink, X-Band Downlink (five and dime)**
- **Provide Frequency/Time Locking Capability for the Ground Station**
- **Utilize SDR technology to maximize flexibility to Experiment and Modify Operation**
- **Optimize Satellite architecture to minimize Ground Station costs**
- **Provide for maximum Power Weighting @Output for the downlink to prevent satellite capture**
- **UHF/VHF/L-Band/S-Band/HF optional Uplinks**
- **Provide a Digital Downlink of Satellite Data**
- **Provide a Digital Downlink of ID, Time stamp, Location (ala GPS/Grid Square) and uploaded TLE**
- **Provide for a DVB-S2 Input & Output when available**
- **Build in Redundant paths where feasible**
- **Provide multiple Digital Downlink paths**
- **Provide multiple Voice Downlink paths with different modulation types**
- **Provide a Multi-channel In- Single Channel out for contact Initiation and/or emergency channel**
- **Provide a controlled Ham Band Scanner Survey Downlink Capability**

General Approach

- Build and Demonstrate an example Ground and Satellite system that gives the user a sense of what a modern satellite system might look and feel like
- Concentrate on the system, not the implementation
 - *Talk to me about GNU Radio flow graphs at the demonstration area*
- Incorporate the latest technology that is available and cost effective
- Use hardware and software that is identical or mimics planned future systems
- Make the communication architecture programmable to facilitate experimentation and optimization
- Use COTS SDR(s) likely to be used to facilitate early launch opportunities

Demonstration Approach

Satellite Demo:

- Use *available* ETTUS SDR (N210) instead of the E310 or B205 that is desired.
- Use a laptop running GNU Radio software with UBUNTU Linux
 - *GNU Radio SW is loaded internally in the E310 version, but we needed a display*
- Use a cheap RTL-SDR as the second satellite receiver

Ground Station Demo:

- Use *available* ETTUS SDR (N210) instead of the E310 or B205 that is desired.
- Use a laptop running GNU Radio software with UBUNTU Linux
 - *GNU Radio SW is loaded internally in the E310 version, but we needed a display*
- Use a cheap RTL-SDR as the local receiver in place of a microphone input

Ascent Demonstration- AMSAT Symposium

0.44, 1.26, 2.4, 3.4 GHz bands

~~~5.6 GHz~~

0.145, 0.44, 1.26 GHz bands

0.4 to 4.4 GHz

0.145, 0.44, 1.26 GHz bands

*Local Receiver added &  
Tuned to VHF/UHF  
For this Demonstration Only*

What should be inside the SDR

## 'Satellite' Computer

- Receives Ground Station C-band
- Demodulates Uplink signals, both Digital and Analog
- Cleans them up and weights them for retransmission
- Adds frequency/time lock signal
- Adds any cmd downlink and msg
- **Transmits to Ground (Downlink)**

## Ground Station Computer

- **Receives Local Transmissions**
- **Converts Audio for uplink**
- **Transmits Audio(s) to 'Satellite'**
- Receives Sat Sim via X-band
- Processes received Data stream
- Locks Frequency
- Selects output channel(s)

Uplink-1 Receiver

Uplink-2 Receiver

Uplink Transmitter

Local Receiver

Downlink Transmitter

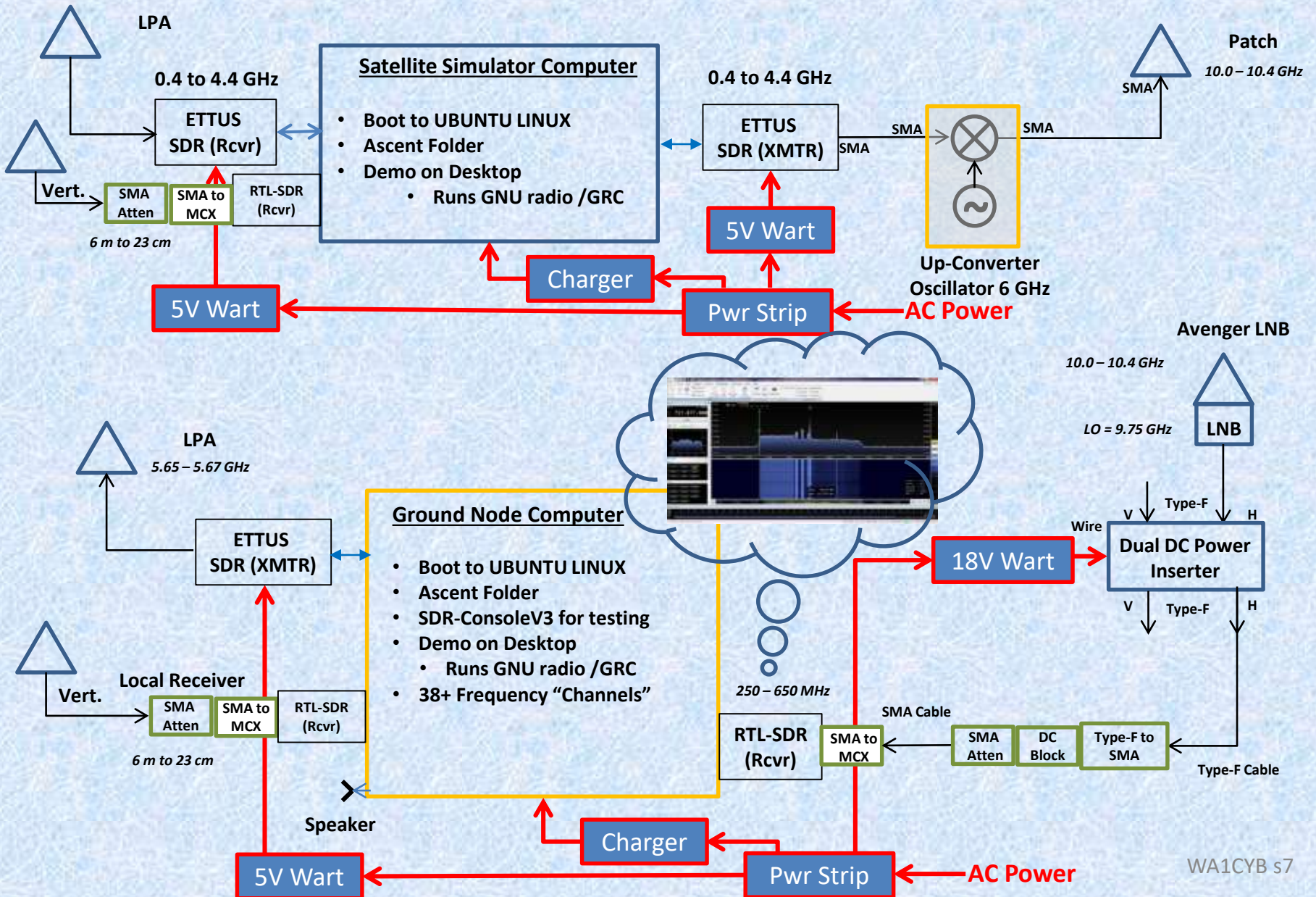
Downlink Receiver

LNB

~10.3 GHz

~0.6 GHz

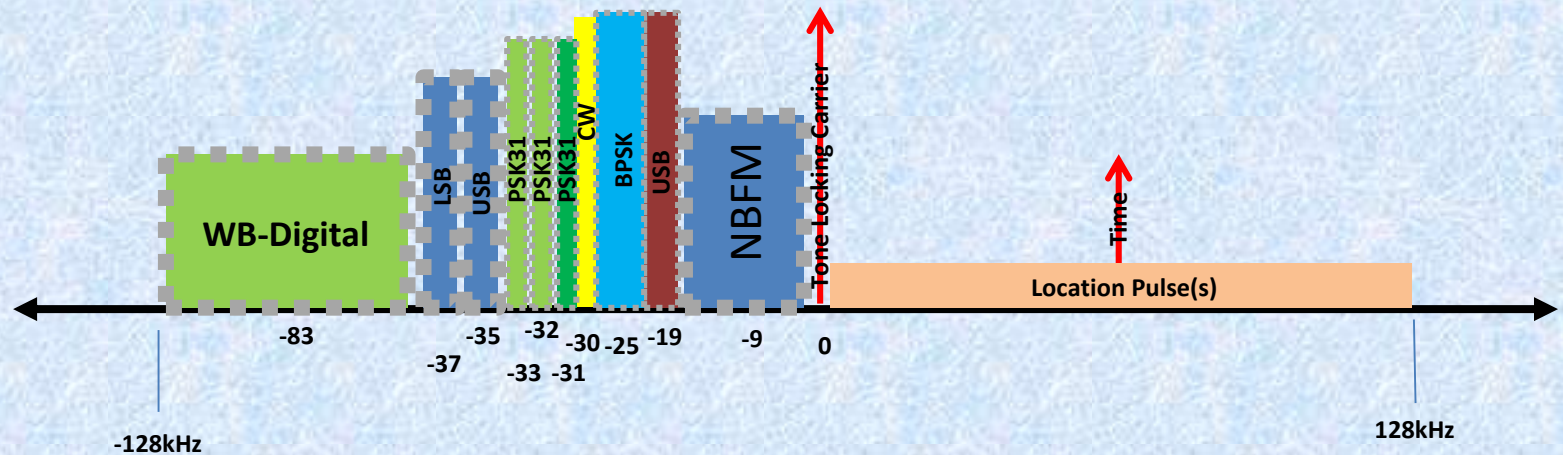
# 3U Satellite Demo Connection Diagram (Commo)





# Example Downlink Frequency Band Plan

## Arbitrary Peak Weighting

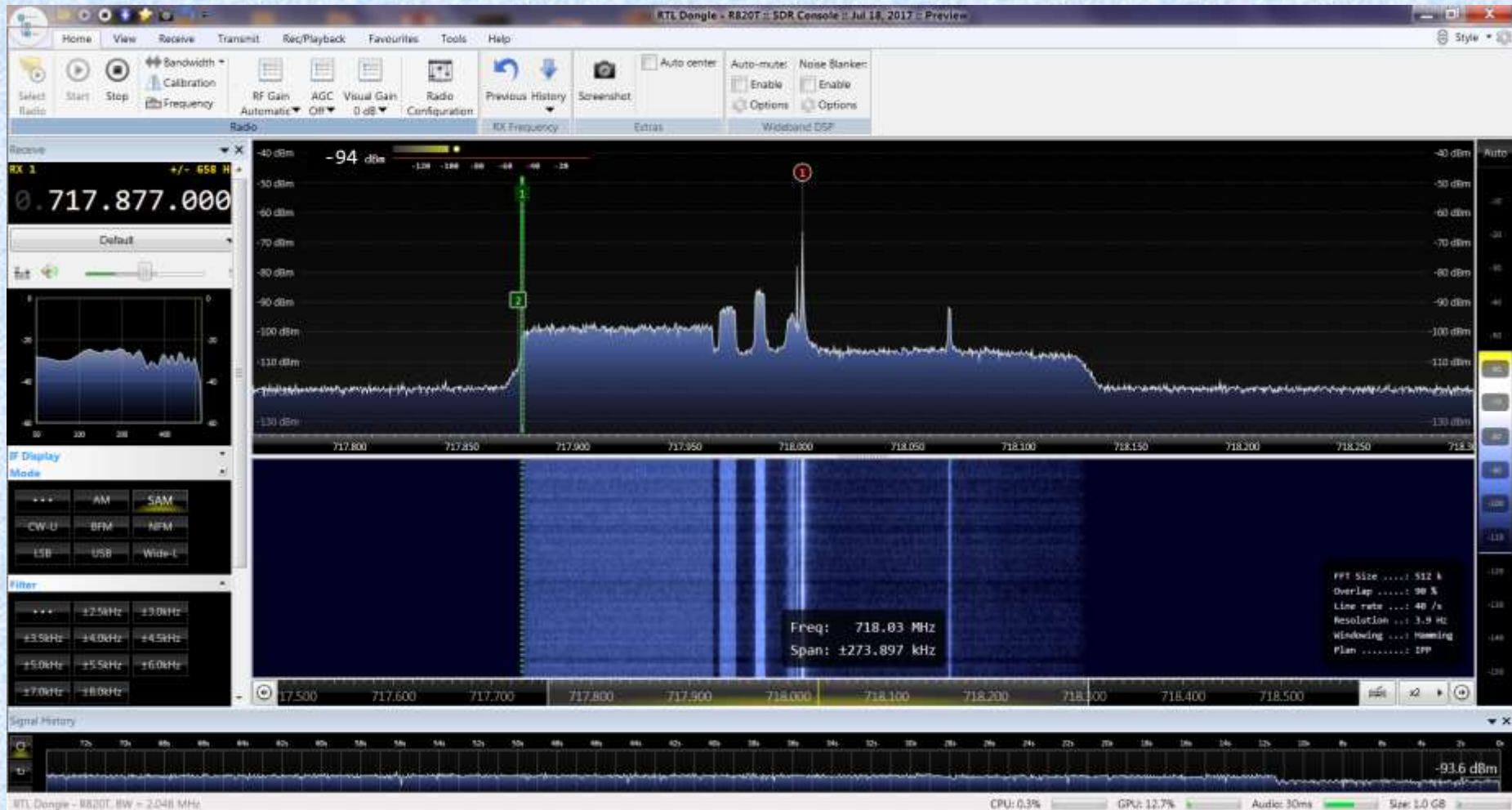


1. Tone Locking Carrier: Enables Ground Lock of Spectrum when Doppler is present
2. NBFM: Voice Channel(s) Translated from a Low Band
3. USB: Combined Multi-channel In Initiate contact and/or emergency channel down
4. BPSK: ID, Telemetry and data stream from satellite
5. CW: CW Bandwidth(s) Translated from a Low Band
6. PSK31-3: Satellite broadcast of ID, Time stamp, Location (ala GPS) and TLE
7. PSK31-2: Chat Channel #2
8. PSK31-1: Chat Channel #1
9. USB: Channel #3
10. LSB : Channel #4
11. Wide Band Digital: Channel #5
12. Location Pulse(s): Enables Precise Ranging/Location

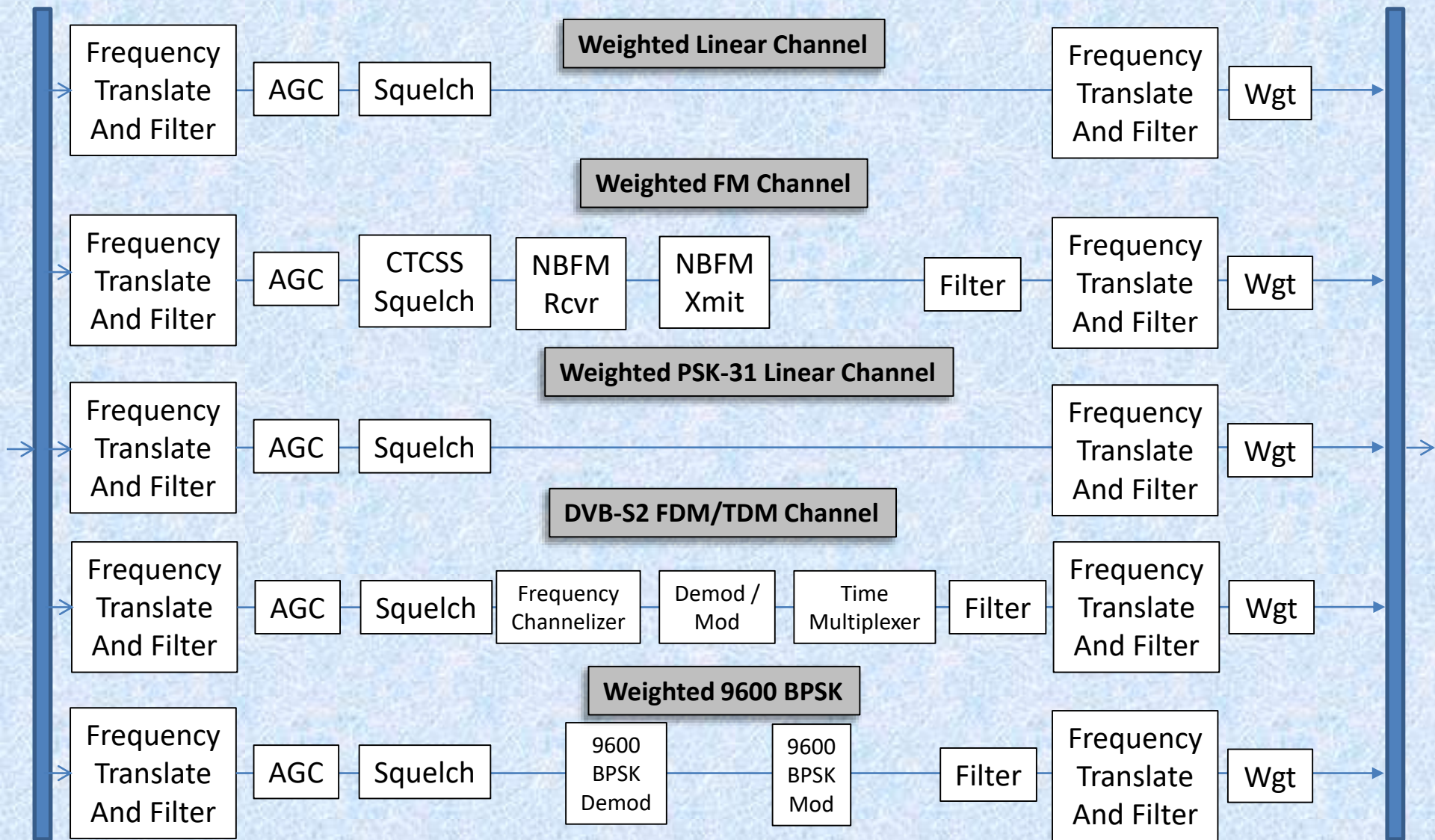


# As Seen at Avenger LNB Output

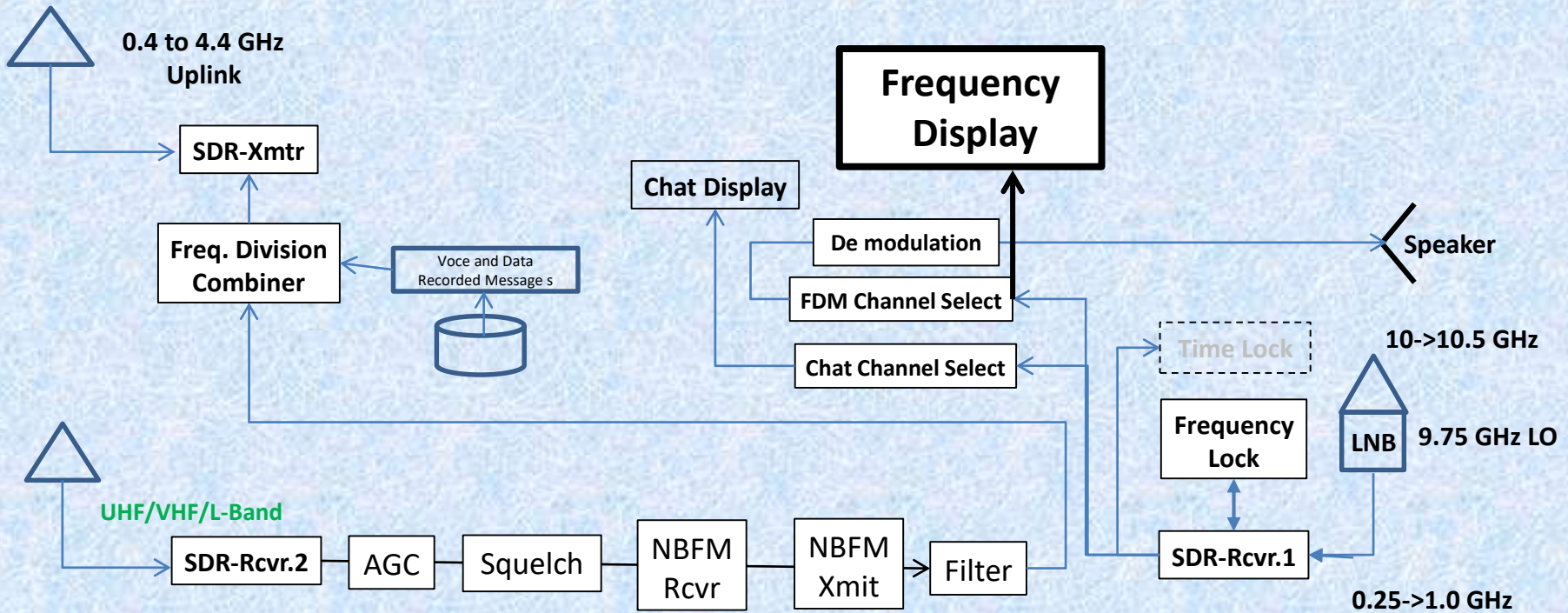
(Noise in at 5.5 GHz, Few channels enabled, Sat Out at 10.45 GHz)



# Example Channel Breakdowns



# Demo Ground Station



## Local Receiver

Tuned to a ham band

RTL: freq. <1300 MHz



# Amateur Radio Science Experiment Possibilities

- 2<sup>nd</sup> receiver can be tasked to do other functions
- Conduct an Amateur Frequency Survey (multi-bands)
- Examine propagation via WSPR and WJT modes
- Upper atmosphere scattering
- Urban noise sources versus frequency etc.
- Multiple frequency inputs on different bands with common output band channel (Cross band input) for emergency use. “Hoot and Holler” Conference call
- Shared Aperture Antenna Steering
- Automatic logging of satellite users/peak signal level /vs satellite location
- Very weak satellite transmitter power beacon experiments (no power amplifier, straight SDR power)
- Even more satellite input frequency receivers (1 chip for each 2 frequency bands)
- Harmonic beacons for frequencies above x-band..... endless possibilities!

~5 Minutes to Transfer 1 Complete Set of Measurements Using 1 Output Channel

|              |        | Bits                         | Bits             | Bits            |
|--------------|--------|------------------------------|------------------|-----------------|
| Total Points |        | 32 bit Xfer min.             | 16 bit Xfer min. | 8 bit Xfer min. |
| 94,510       | points | 3,024,896                    | 1,512,736        | 756,656         |
|              |        |                              |                  |                 |
|              |        | ~UNCOMPRESSED Downlink Times |                  |                 |
|              |        | seconds                      | seconds          | seconds         |
|              | Rate   | Time to Xfer                 | Time to Xfer     | Time to Xfer    |
|              | 1200   | 2,521                        | 1,261            | 631             |
|              | 9600   | 315                          | 158              | 79              |
|              | 24000  | 126                          | 63               | 32              |
|              | 48000  | 63                           | 32               | 16              |



# Go See the Demonstration!

- The Following slides show in a series of 5 test builds what the satellite could do
- If you want to build your own system, start with the simplest linear satellite (sat\_test\_1)
- Git-hub site has all the sat\_test flow diagrams
- Helpful Notes contained in the flow graphs

## Sat-test\_1.grc

- Linear repeater +/- 128 kHz w/ single agc and squelch
- CW tone at the output center frequency,  $f_{0out}$
- ID (cw) at  $f_{0out} - 30.5$  kHz
- Pseudo Doppler available (As if in LEO or higher orbit)

## Sat-test\_2.grc

- Sat\_test\_1.grc capability plus
- Added nbfm channel at receive center frequency,  $f_{0in}$
- Added nbfm output at  $f_{0out} - 9$  kHz
- Squelch shown set low, Noise in nbfm Channel only
- Audio enabled for demo purposes

## Sat-test\_3.grc

- Sat\_test\_2.grc capability plus
- Shifted 128kHz of input to  $f_{0in} - 62.5$  kHz

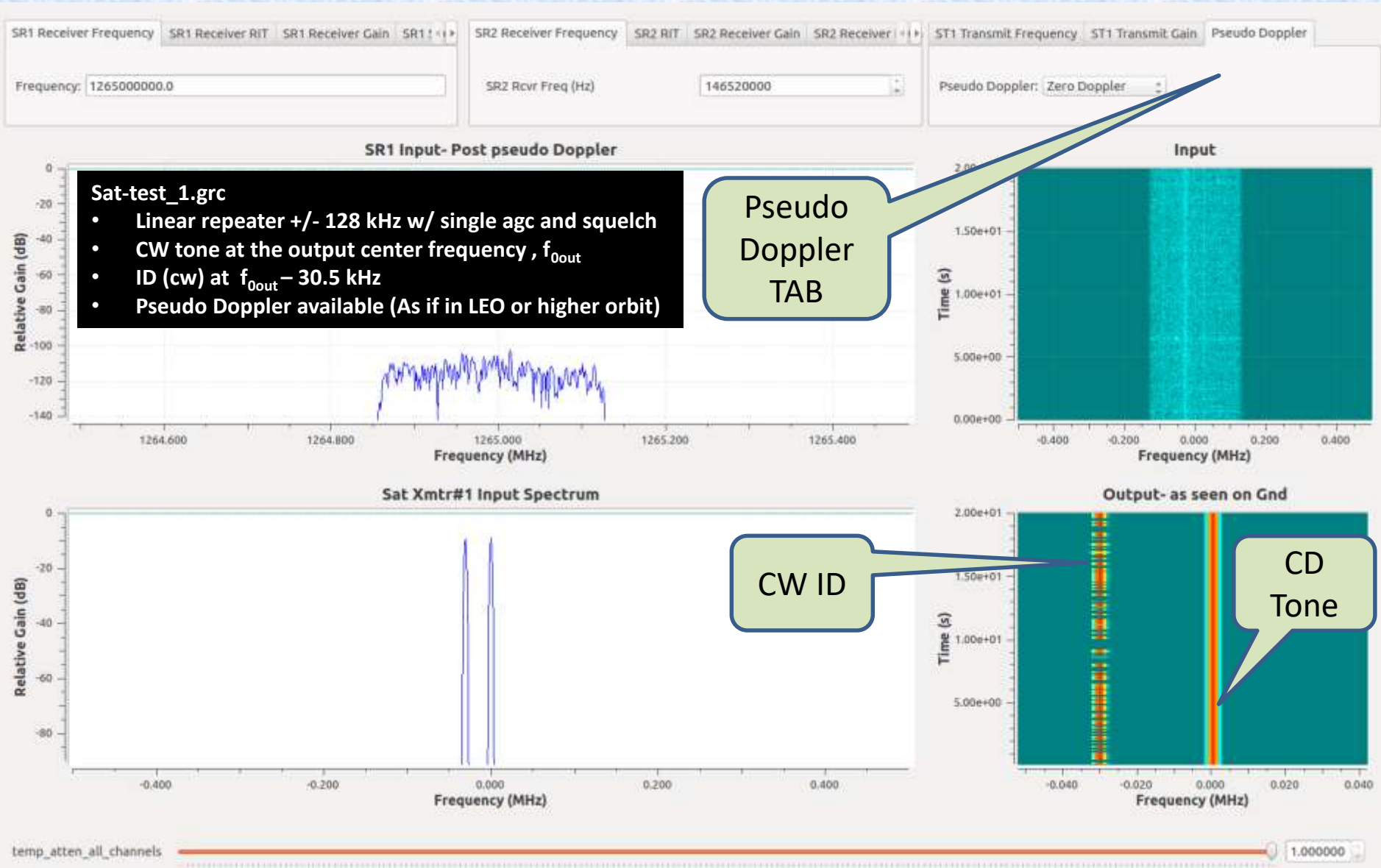
## Sat-test\_4\_r3.grc

- Sat\_test\_3.grc capability plus
- 250 kHz noise shifted up 12.5 kHz and attenuated 100 dB
- Added 32 (30 useable) linear channels (1.95 kHz bw)
  - Output 30 channels at  $f_{0out} - 125$  kHz to  $f_{0out} - 62.5$  kHz
- Added 8 input channels (7 useable) linear channels (7.81 kHz bw)
  - Lower edge of the bank at  $f_{0out} - 13$  kHz, upper edge at  $f_{0out} - 59$  kHz
- Note that cw ID is also placed in the lower part of the 3<sup>rd</sup> filter from nbfm
- Second receiver (SR2) enabled
- Linear output of SR2 placed in the 1<sup>st</sup> filter from nbfm

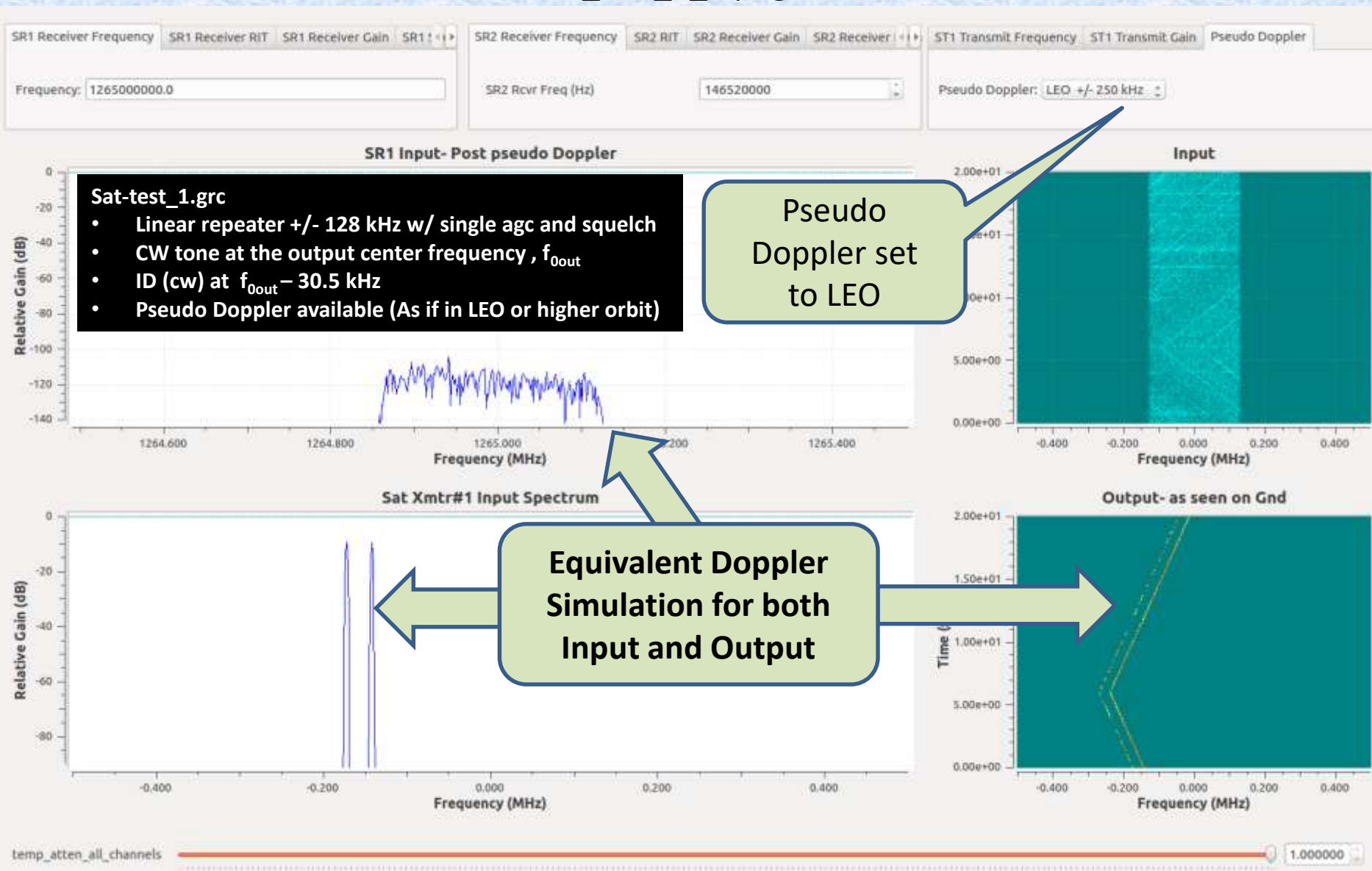
## Sat-test\_5.grc

- Sat\_test\_4\_r3.grc capability plus
- Adjusted nbfm bw on receive
- Added three psk31 transmit streams, 1kHz apart, each with ID text
  - Three placed in 4<sup>th</sup> 7.81 kHz linear channel at  $\sim f_{0out} - 40$  kHz
  - Placed another psk31 stream on a reduced output upper stream
    - Output frequency just under  $f_{0out} - 125$  kHz
- Maxes out current external computer resource used for development

# sat\_test\_1\_0.png



# sat\_test\_1\_1.png

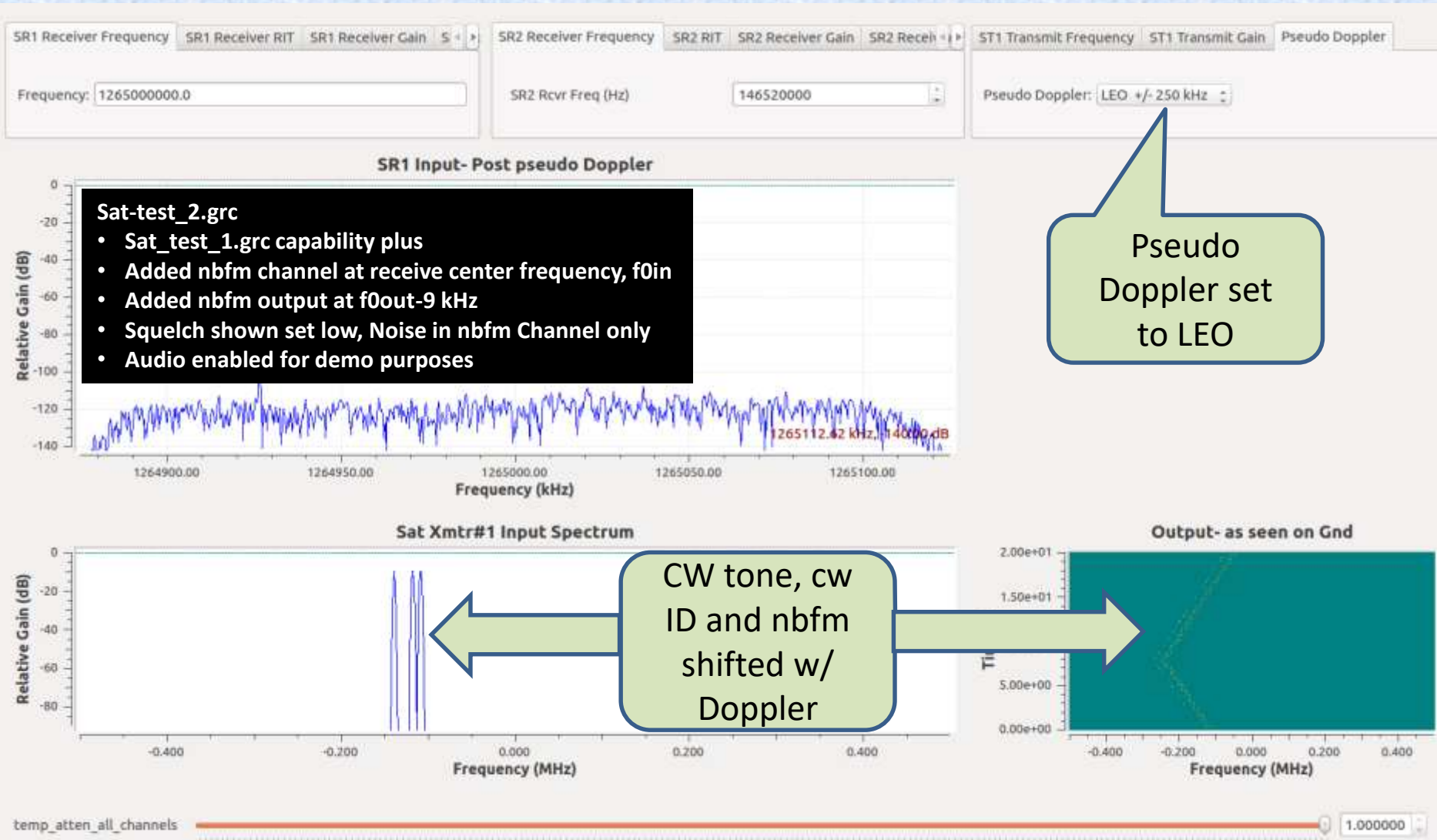


# sat\_test\_2\_0.png





# sat\_test\_2\_1.png



sat\_test\_2\_2.png

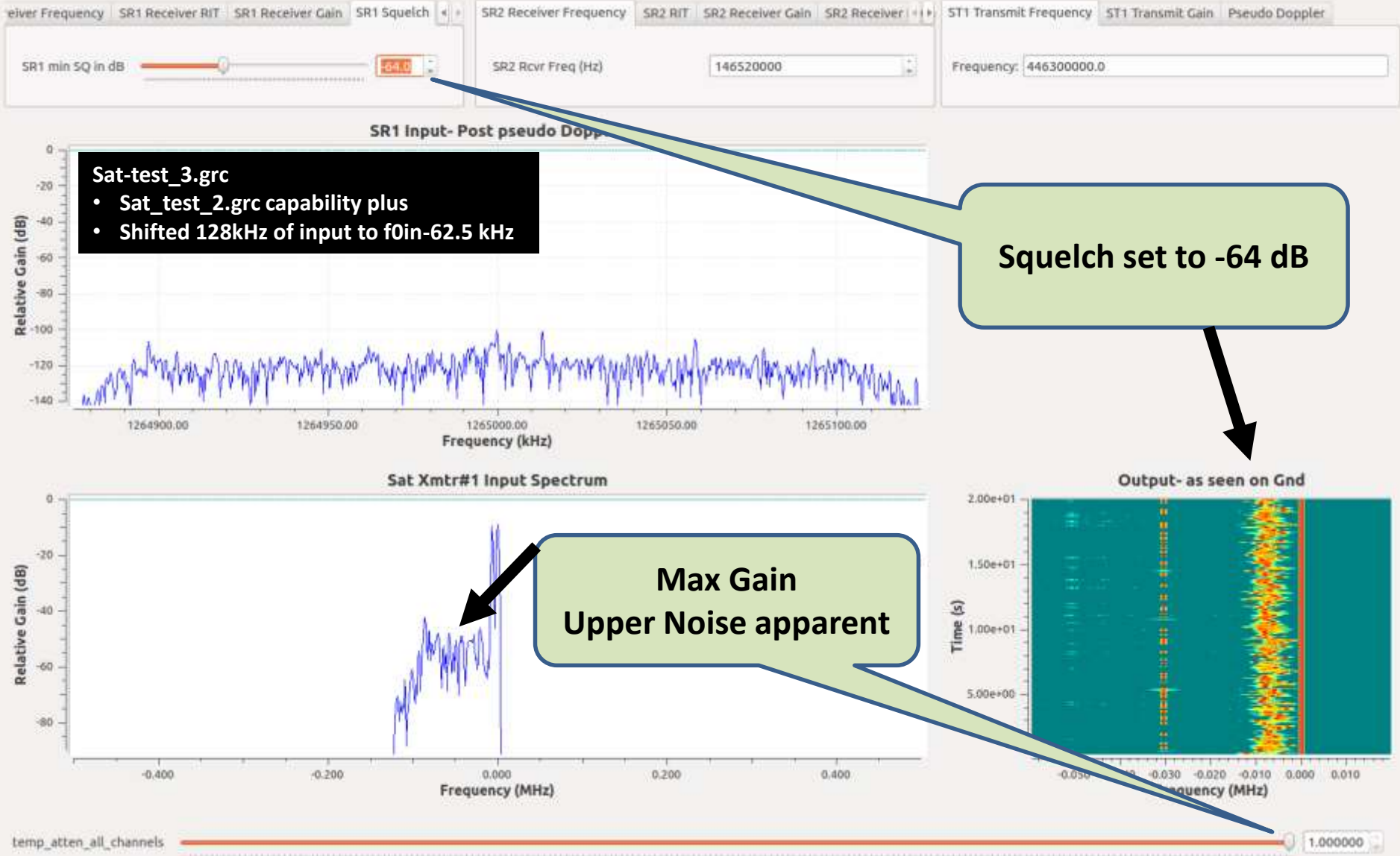


# nbfm Modulation

# sat\_test\_3\_0.png

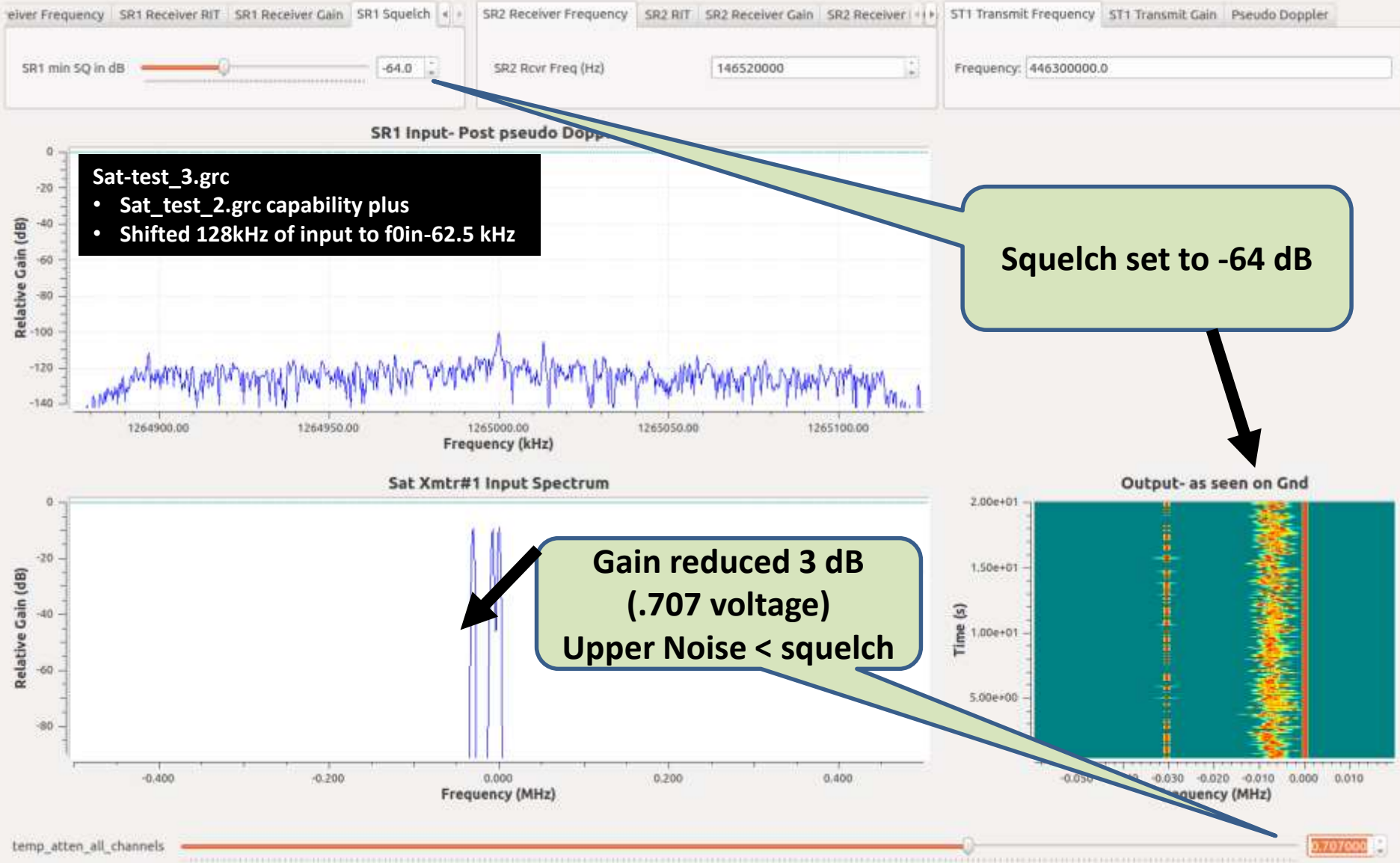


# sat\_test\_3\_1.png

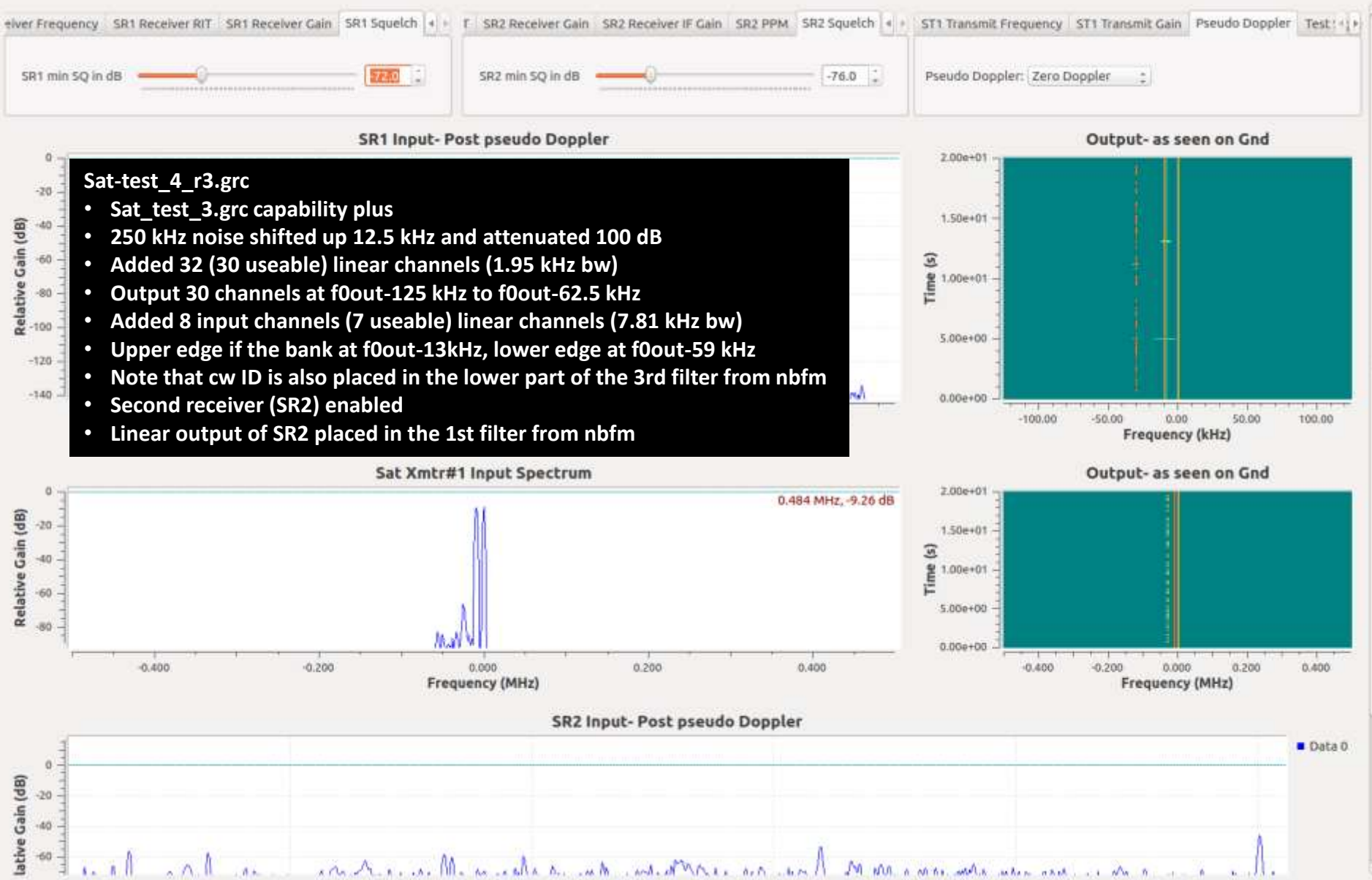




# sat\_test\_3\_2.png



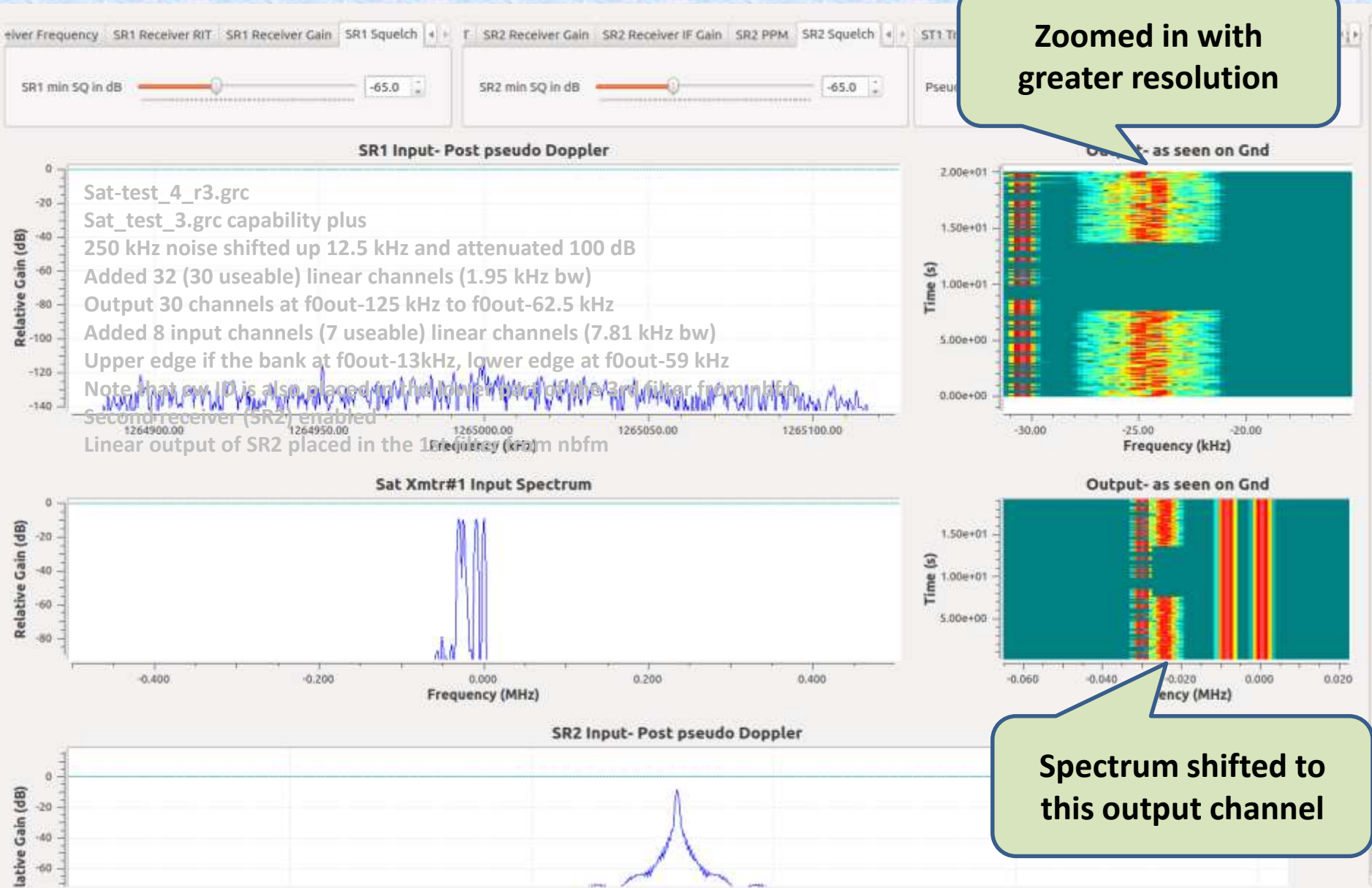
# sat\_test\_4\_0.png



# sat\_test\_4\_2.png

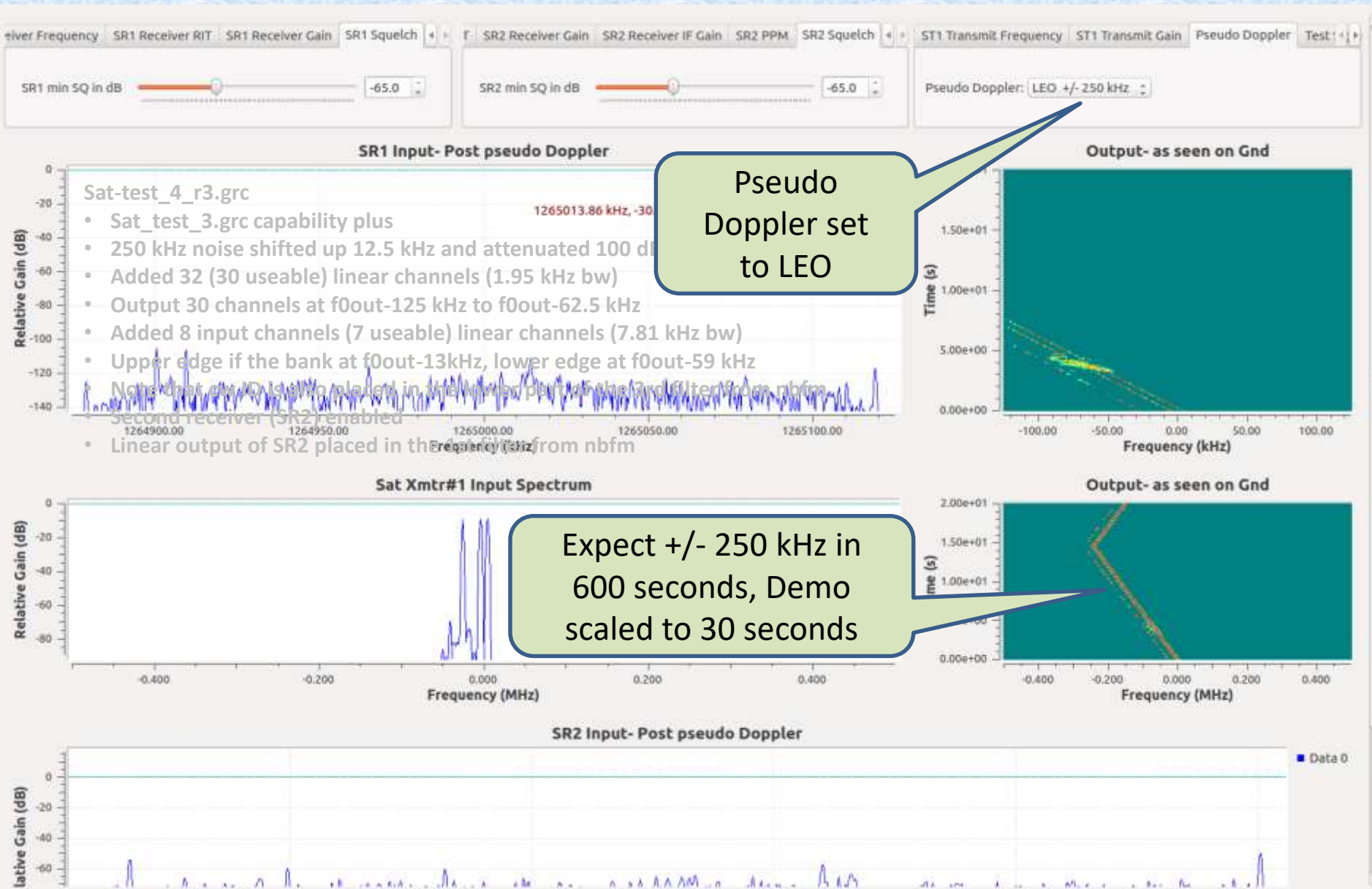


# sat\_test\_4\_3.png

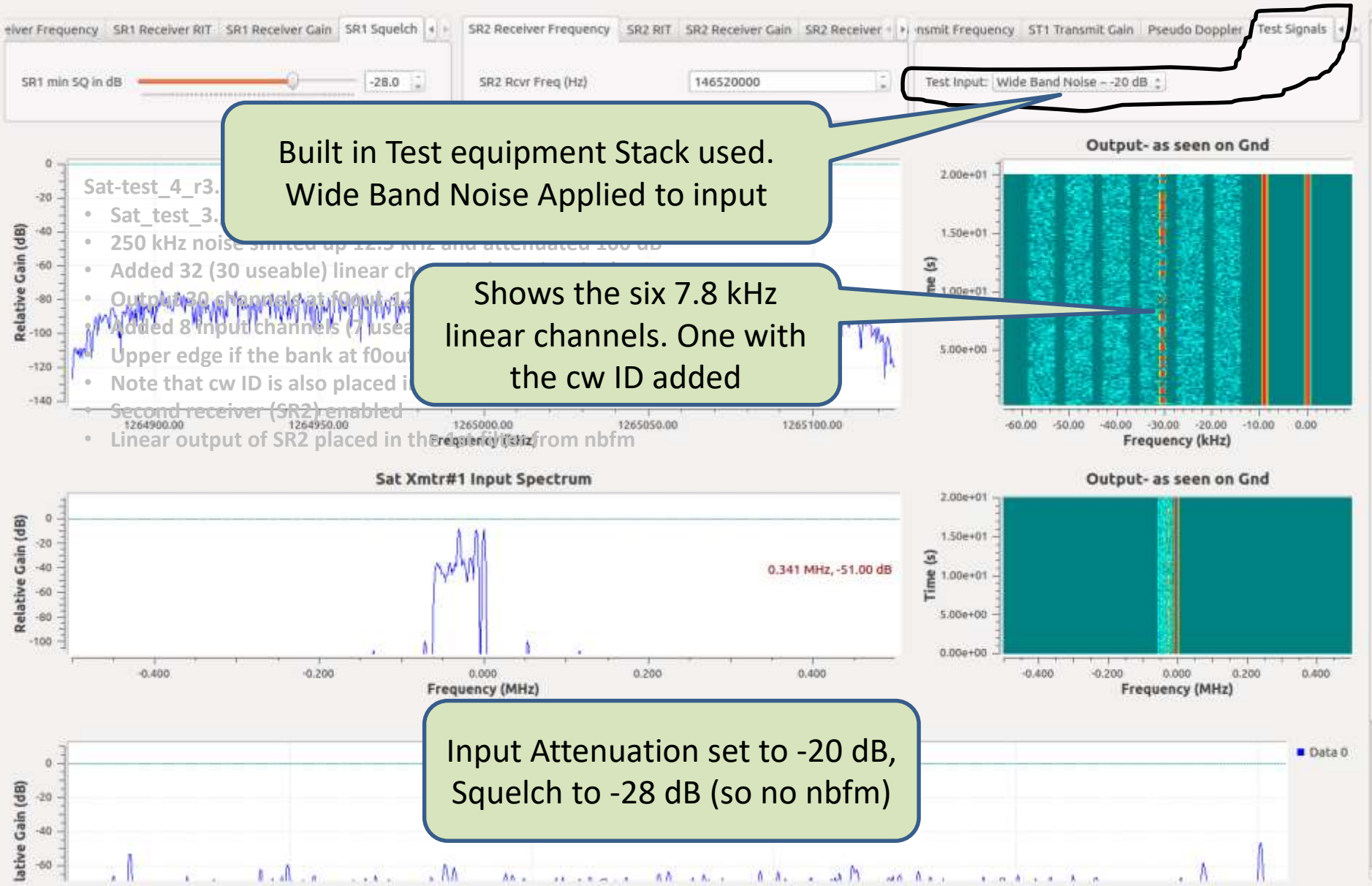




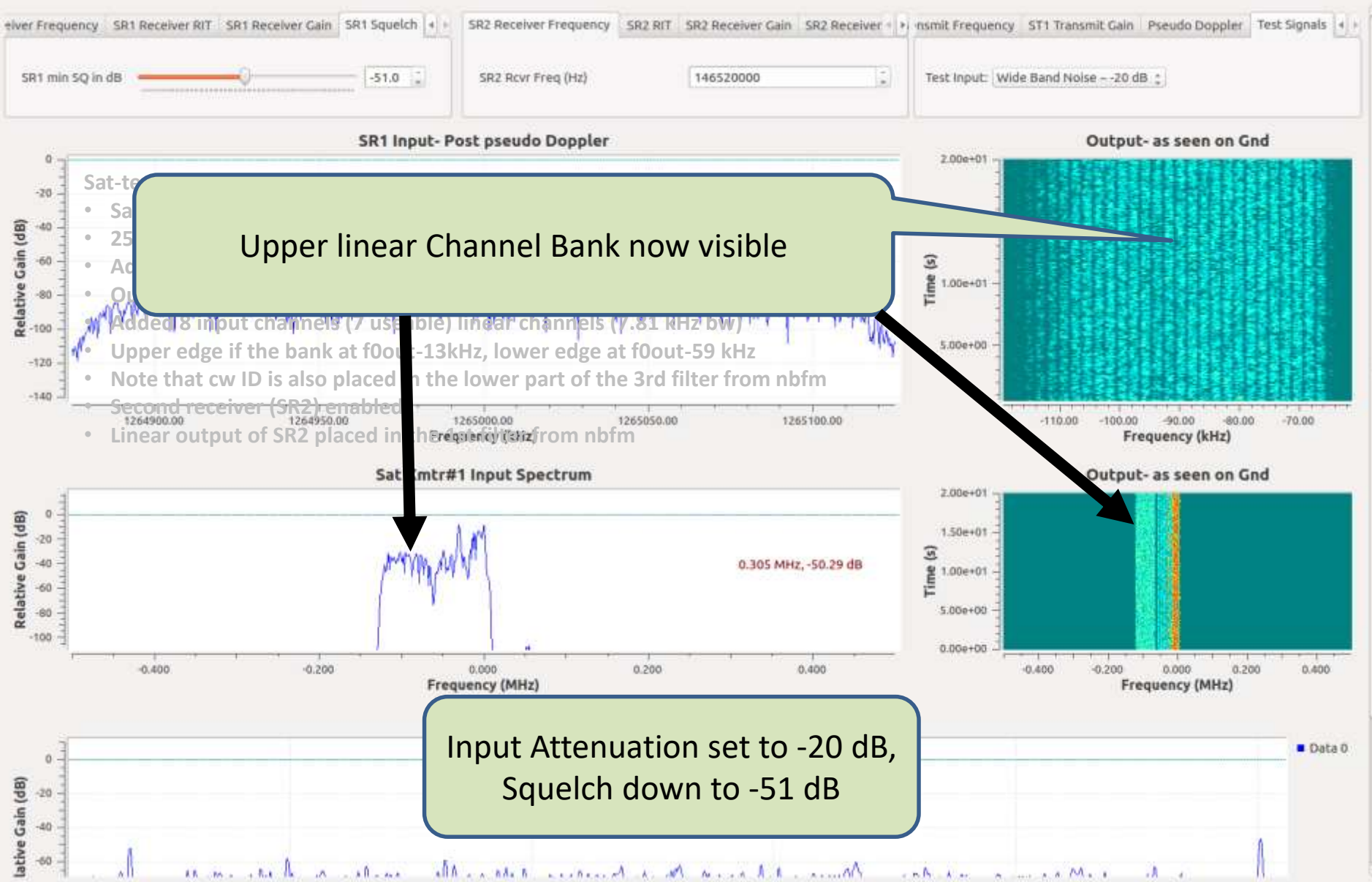
# sat\_test\_4\_4.png



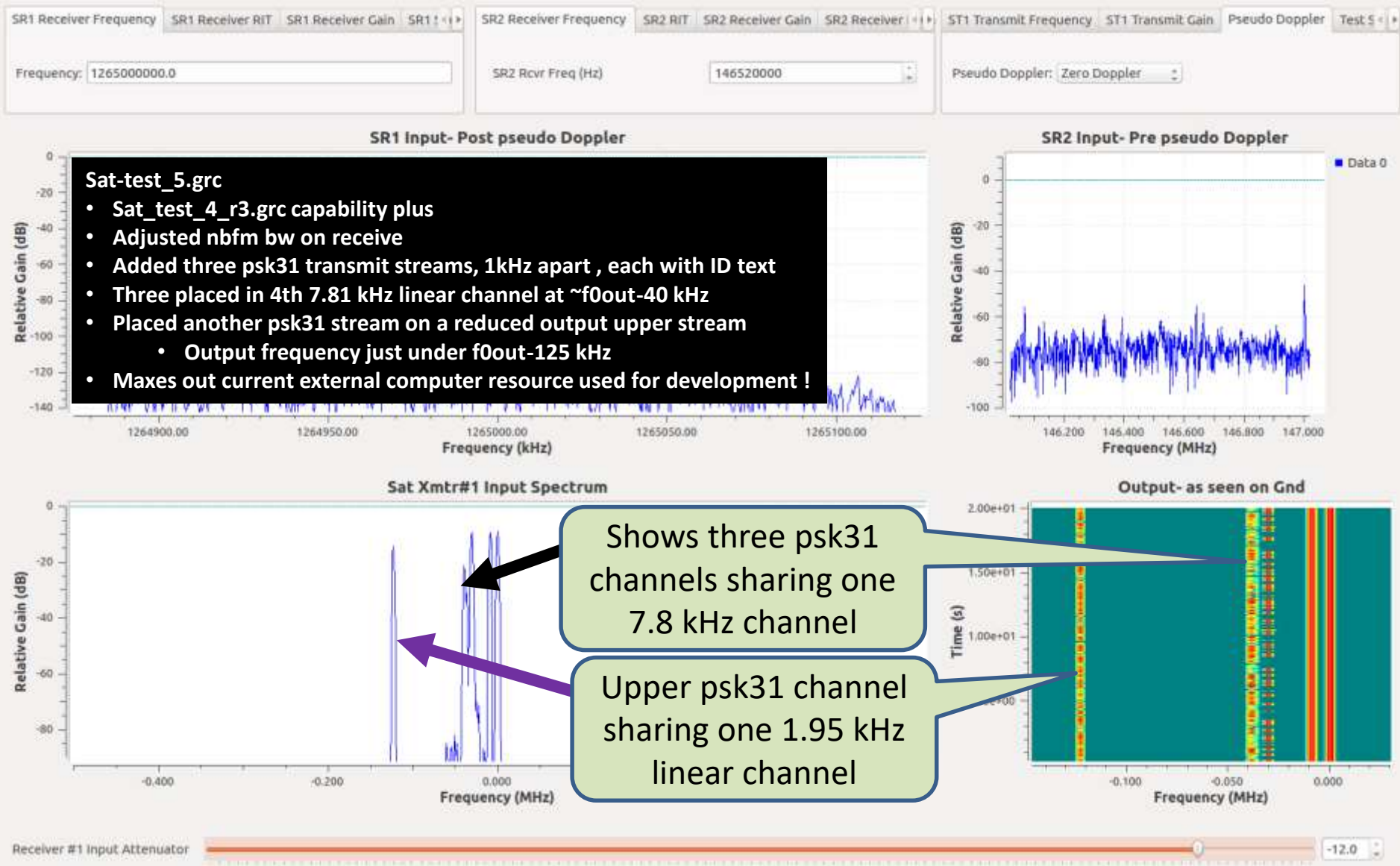
# sat\_test\_4\_6.png



# sat\_test\_4\_7.png

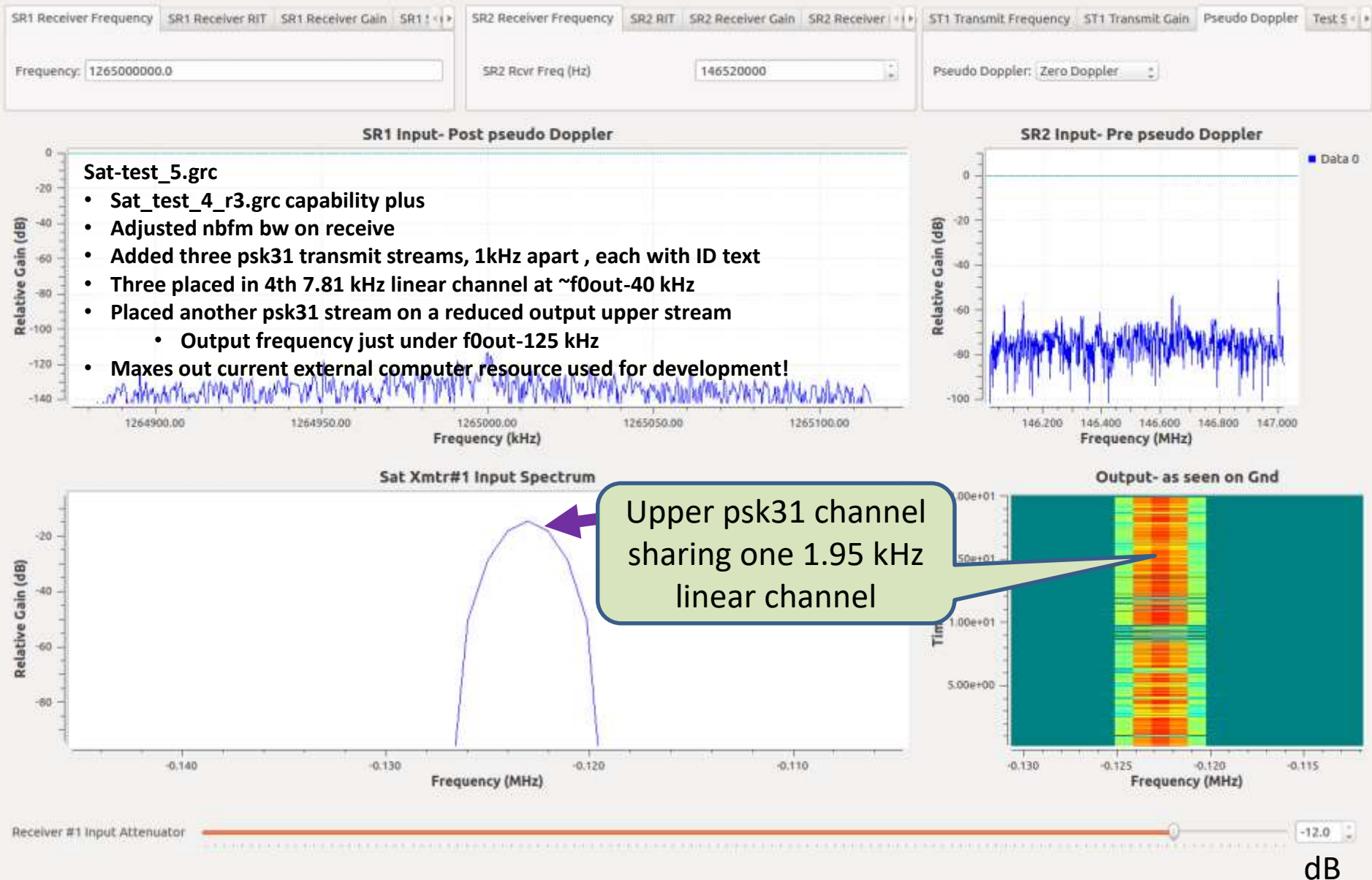


# sat\_test\_5\_0.png





# sat test 5 1.png



sat\_test\_5\_2.png

SR1 Receiver Frequency: 1265000000.0  
SR1 Receiver RIT: [empty]  
SR1 Receiver Gain: [empty]

SR2 Receiver Frequency: 146520000  
SR2 RIT: [empty]  
SR2 Receiver Gain: [empty]

ST1 Transmit Frequency: 446300000.0  
ST1 Transmit Gain: [empty]  
Pseudo Doppler: [empty]

**SR1 Input- Post pseudo Doppler**

Sat-test\_5.grc

- Sat\_test\_4\_r3.grc capability plus
- Adjusted nbfm bw on receive
- Added three psk31 transmit streams 1kHz apart each with ID text
- Three placed in 4th 7.81 kHz linear channel
- Placed another psk31 stream on a
  - Output frequency just under
- Maxes out current external comp

Shows three psk31 channels sharing one 7.8 kHz channel - Better resolution -

**Sat Xmtr#1 Input Spectrum**

Upper linear Channel Bank not visible, Not breaking squelch

**Output- as seen on Gnd**

Receiver #1 Input Attenuator: -12.0

WA1CYB s30

- Sat\_test\_4\_r3.grc capability plus
- Adjusted nbmf bw on receive
- Added three psk31 transmit streams 1kHz apart each with ID text
- Three placed in 4th 7.81 kHz linear
- Placed another psk31 stream on a
  - Output frequency just under
- Maxes out current external compu

Shows three psk31 c  
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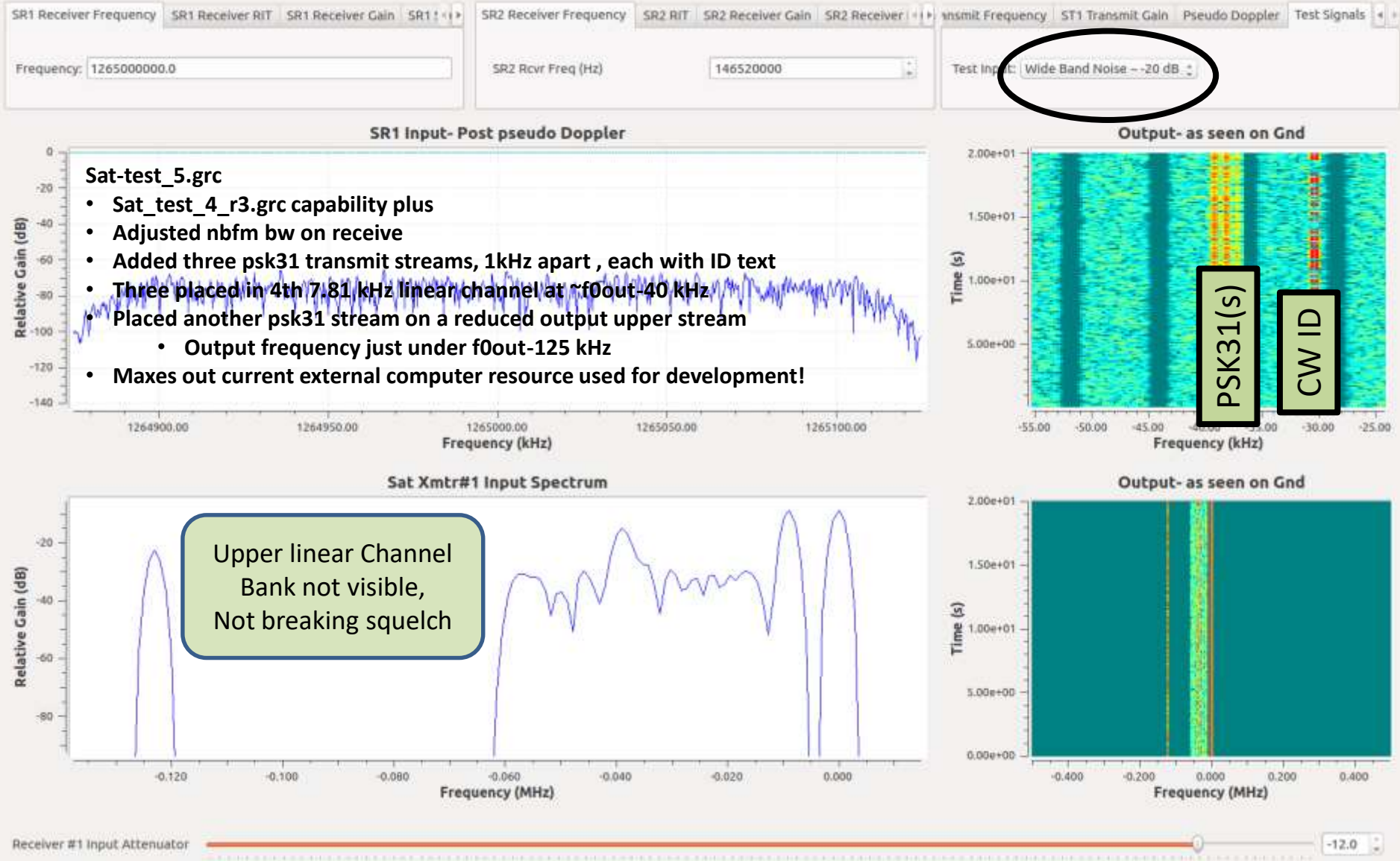
Shows three psk31 channels  
sharing one 7.8 kHz channel  
- Better resolution -

Upper linear Channel  
Bank not visible,  
Not breaking squelch

Receiver #1 Input Attenuator

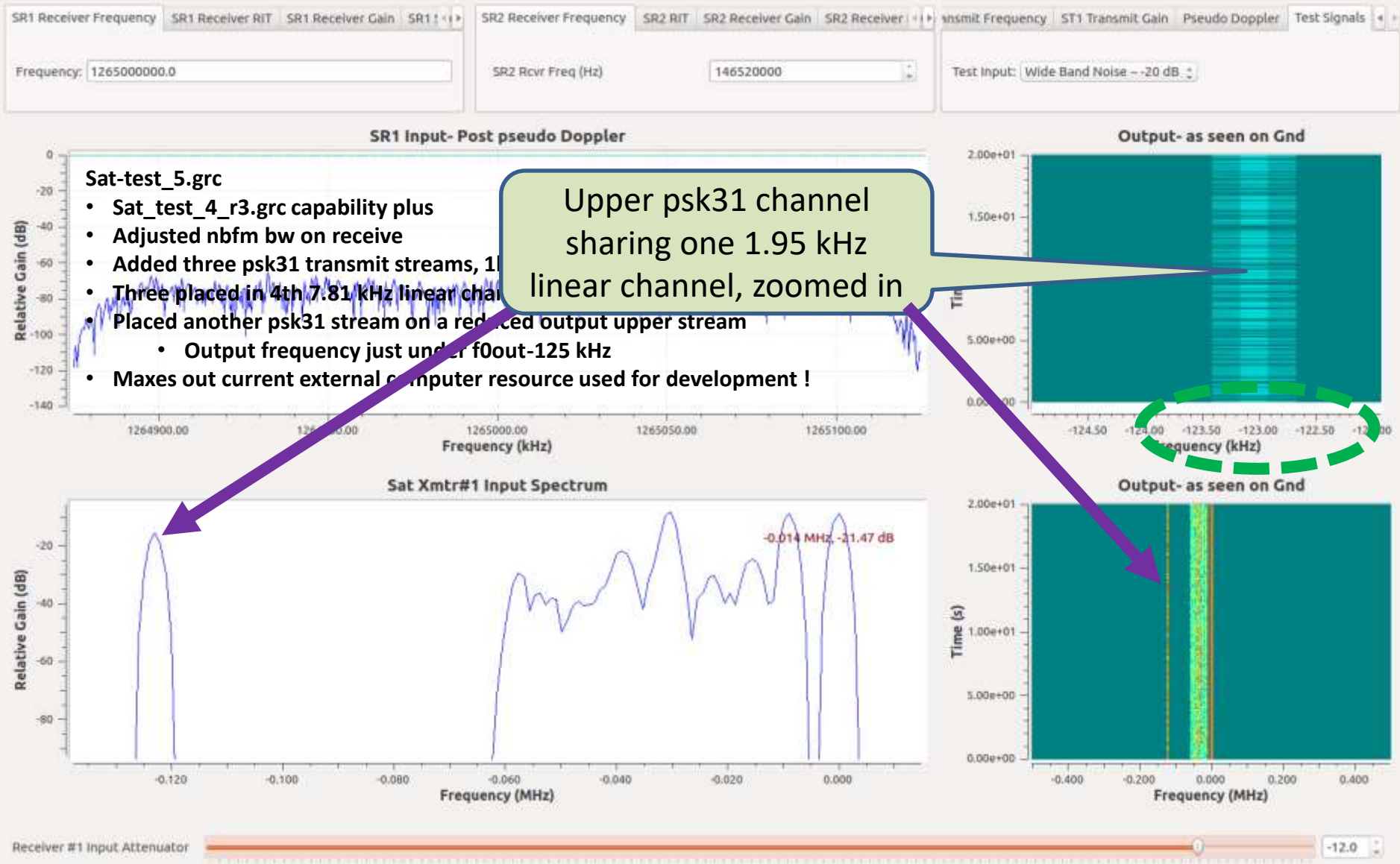
-12.0

# sat\_test\_5\_3.png



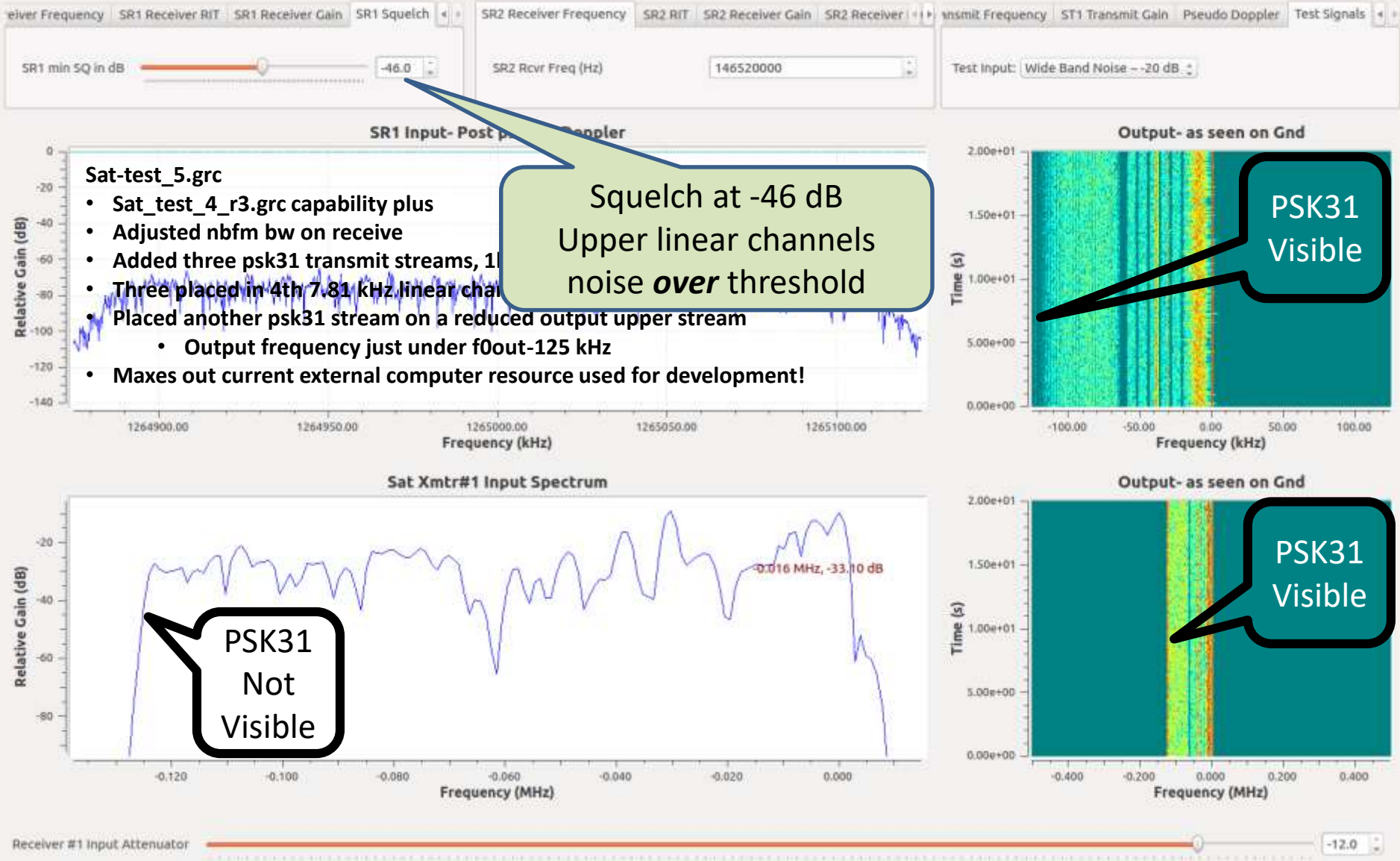


# sat\_test\_5\_4.png

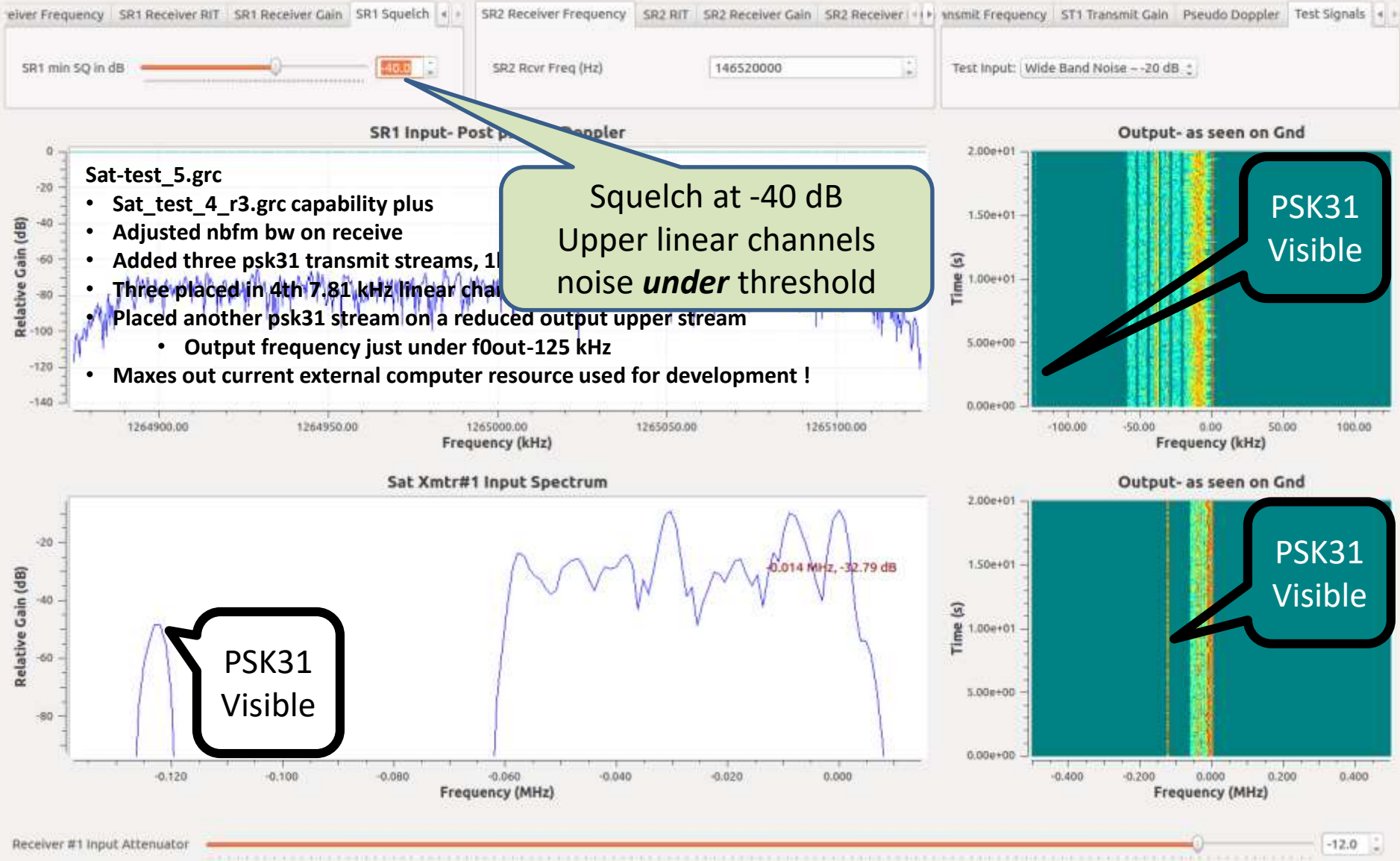




# sat\_test\_5\_5.png



# sat\_test\_5\_6.png



**Go See the Demonstration!**

# Operational Procedure- rev A

|                                                                                                                                                 |  |  |  |
|-------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|
| <b><u>Operation of the Ground Station</u></b>                                                                                                   |  |  |  |
| 1 Warm up receiver and LNB                                                                                                                      |  |  |  |
| 2 Run Frequency Calibration using ATSC pilots (Resulting error between 500 and 650MHz is less than 100 Hz)                                      |  |  |  |
| 3 Turn GS receiver on SDR w/ LNB), input offset if needed                                                                                       |  |  |  |
| 4 Turn GS C-band transmitter at known frequency and look for 2 <sup>nd</sup> Harmonic in GS receiver SDR w/ LNB)                                |  |  |  |
| 5 Measure Offset error and save, This is the LNB error + transmitter error + corrected SDR receiver error (GS error). Restart if required       |  |  |  |
| 6 Wait for Satellite, monitor beacon frequency range                                                                                            |  |  |  |
| 7 After CW/Range beacon is visible, Center manually on the display. This is the GS error+ Satellite error + Doppler + Satellite frequency error |  |  |  |
| 8 Subtract the GS error in step 5 from the measured frequency in step 7. This is the Satellite error + Doppler + Satellite frequency error      |  |  |  |
| 9 Turn on the Satellite error + Doppler + Satellite frequency error lock circuit                                                                |  |  |  |
| 10 All receiver channels should be locked to the satellite and track it within +/-250Khz (LEO X-band)                                           |  |  |  |
| 11 Transmit with selected offset (channel) on a unused channel                                                                                  |  |  |  |
| 12 Verify receiver picks up transmitter on frequency translation to X-Band.                                                                     |  |  |  |
| 13 Antenna Rotation Control not demonstrated (this time)                                                                                        |  |  |  |
|                                                                                                                                                 |  |  |  |
| <b><u>Operation of the Satellite Station</u></b>                                                                                                |  |  |  |
| 1 Warm up SDRs (Receiver and Transmitter)                                                                                                       |  |  |  |
| 2 Bypass command structure and turn on system manually                                                                                          |  |  |  |
| 3 Enable CW/Range Beacon                                                                                                                        |  |  |  |
| 4 Enable C-band receiver Band                                                                                                                   |  |  |  |
| 5 Enable Transmitter                                                                                                                            |  |  |  |
|                                                                                                                                                 |  |  |  |
| <b><u>System Operation Verification</u></b>                                                                                                     |  |  |  |
| 1 Use HT to talk to ground station on Channel zero                                                                                              |  |  |  |
| 2 Verify reception on Channel zero on the Ground Station at X-band                                                                              |  |  |  |